No. 6.— *Notes on Invertebrate Fossils, with Descriptions of New Species*

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1. Pachytheca and Eggs of Trilobites

Several years ago I became interested in the so-called eggs of trilobites, described by Barrande from Silurian and Devonian deposits in Bohemia. One of the three types which he illustrated is represented by spherical bodies averaging about 4 mm. in diameter, and these, when sectioned, proved to have a very remarkably well preserved internal structure. Although their real nature is not yet fully understood, it is obvious that they are not eggs. After showing them to a number of zoölogists and botanists, without finding anyone who was acquainted with their nature, I stumbled upon a brief description of *Pachytheca,* and, upon looking up that genus, found that these large "eggs" must be referred to it. At this juncture the late Professor Lincoln Ware Riddle took up the study of the material with characteristic enthusiasm, and expected to describe it, but his unfortunate illness and much regretted death prevented his doing more than to make a few notes and some camera-lucida sketches. The algal nature of *Pachytheca* seems pretty generally admitted, but it does not appear possible to point to any exactly similar structure among modern plants, so that the nature of the organism has not as yet been fully demonstrated. The remarkable state of preservation of the Bohemian material permits the observation of certain facts not previously known. It is in the hope of assisting in the explanation of this curious structure that the accompanying notes and figures are presented.

Spherical Eggs

In his classic work on the trilobites of Bohemia, Barrande described three kinds of spherical bodies, which he considered to be the eggs of trilobites. All were usually black in color and the distinction was made on the basis of size. The largest were from 4 to 5 mm., the medium-sized ones were about 2 mm. and the small ones did not exceed .66 mm. in diameter. The specimens of the two larger sizes were reported as being rare and always found isolated, whereas the very small ones were abundant, great numbers occurring together in the same piece of rock.

Barrande's reasons for thinking that these objects might be the eggs of trilobites were:

1. They are never found except in localities where there are many fragments of trilobites.
2. In each of the three sorts the diameter is constant.
3. The spheroids are always black, whatever the nature of the rock, except in the red strata of Division H.
4. The shell is thin and opaque, and easily detached by a blow. The surface is brilliant as if polished. The interior, filled with semi-translucent calcite, in some cases shows black spots and at the center a crystalline nucleus.
5. Not all the specimens are preserved as spheres, but some are crushed and bent in a way to suggest great flexibility of the corneous envelope.
6. The larger spheres, the form of which is almost perfect, show, in the few examples known, a cleft of variable form, such as one would expect to find in an egg which had hatched.
7. The black external surface is always a little wrinkled in the best preserved of the specimens.

Barrande further pointed out that the smallest spheres are of exactly the same diameter as the length of the protaspis of *Sao*. Although no young are known as large as the larger ones (2–5 mm.), still it might be possible that the young of the specialized *Ceratocephala verneuili* and *Cheirurus quenstedti* were of appropriate size.

The larger spheres were reported by Barrande to have been collected from Stage E (Silurian), where they were associated with *Ceratocephala verneuili, Cheirurus quenstedti, Harpes ungula, Goldius edwardsi*, etc. The smallest ones were found in Stages G and H (Lower Devonian), always with the remains of *Phacops fecundus*.

Large Spheres

Plate 1, figs. 1–4, 6, 7

In the Schary collection in the Museum of Comparative Zoölogy, there are specimens of the larger spheres, 4.5 to 5 mm. in diameter, from the Silurian at Butowitz, Lochkow, Wiskocilka, Ohvadka, and Lodenitz, where they are preserved in limestone, and Borek, where they are found in a calcareous shale.

The large spheres with a diameter of 4–5 mm. (Barrande, 1852, p. 276, pl. 27, fig. 3), on sectioning, showed wonderfully preserved structure. In a slice passing approximately through the center of a specimen 4.34 mm. in diameter, there is a large, nearly circular central space filled with clear calcite containing elongate branching tubules. This is 1.8 mm. in diameter. Outside this is a zone of radially arranged, small, hollow, branching tubes, which extend to an outer covering consisting of three coats. The zone filled with radial tubes is 1.1 mm. thick. The outer covering is 0.17 mm. thick and shows an outer, dark layer which is separated only indistinctly from the matrix; a middle zone, with spine-like crystals of clear calcite; and an inner thin dark layer without structure. It is this inner layer which generally forms the coating of specimens broken from the rock, thus explaining the black polished surface remarked upon by Barrande.

The radial tubes, when highly magnified, prove to have walls made up of three coats, an outer and inner dark sheath, separated by a layer of clear calcite. The space between tubes is crossed by very thin transverse septa which are much more prominent in some sections than in others. The tubes bifurcate at least once and in some instances twice in the plane of the radial section. There is also a sort of grouping indicated by irregular polygons in the tangential section which suggests that a single tube may become divided into as many as sixteen before it reaches the outer wall.

Externally, these spheres show no topographical markings other than a single flattened or slightly concave area, which resembles the hilum of a seed. It has about one-sixth the diameter of the whole body, and appears to be the point of attachment. After repeated trials by a number of persons, Dr. H. N. Coryell was the successful operator. A section was obtained through a specimen perpendicular to this depressed area. This individual was one which had been freed from the matrix before sectioning, and, as usual with such specimens, shows only the inner of the three coats. This coat is somewhat thickened beneath the depressed area and this extra thickness extends outward from the area in question for about one-half of a quadrant. The zone of radial structure is about .65 mm. thick at the pole opposite the point of attachment, but at the latter area it is much thinned, the inner wall approaches close to the outer one, and for a distance of about .50 mm. radial elements are lacking. (See pl. **1**, fig. 4.)

Embedded in the clear calcite of the central cavity, arranged in directions approximately radial to a point near the pole opposite to the area of attachment, is a tangled mass of small tubes. Similar masses, without, however, the radial arrangement, are seen in the other slices. I at first took these scattered tubes to be disrupted fragments from the zone of radial structure, but Professor Riddle called my attention to the evidence that they are really vestiges of a disintegrating filling of the cavity in which they lie. These tubes are less straight than those in the radial zone, and seemingly of less diameter. They agree with the former, however, in having a very small lumen. The tube has an outer and an inner wall, separated by a clear structureless zone. The lumen is generally filled with a finely granular substance which appears of brownish color under the microscope. Evidence of the breaking down of the internal structure is seen in two of the slices, where the inner wall of the radial zone seems to have shrunk away from the radial elements.

This disintegration of the tissue within the organism furnishes strong support for the view that *Pachytheca* was a structure which served as a float for some seaweed, and is against the interpretation as a spore or seed.

This organism apparently belongs to the genus Pachytheca, which is supposed to be of algal nature, but about which opinion differs. The original specimens of that genus were found in the "Ludlow bone bed" near Hereford, England, but according to Barber (Ann. Botany, **5**, 1891, p. 157), it occurs at almost all localities in England and Wales where the beds transitional between the Silurian and Old Red sandstone outcrop. Individuals showing the better structure were found in the Wenlock near Malvern, and at Cardiff, Wales. The best description of the fossil is that by Barber, cited above, but the genus was named by Hooker (Ann. Botany, **3**, 1889, p. 135), though mentioned as early as 1839 as "Bufonites" by Murchison in the Silurian System.

Pachytheca, like the "trilobite eggs," is a small spherical body, the exterior marked by a single small pit, only seen in the best preserved specimens. When sectioned, a central cavity is found, surrounded by radiating, branching tubes. The cavity itself also contains irregularly arranged branching tubes like those of the specimens from Bohemia.

These bodies were supposed by Murchison to belong to the "fish" with which they are associated in the "bone bed," but Hooker (Quart. Jour. Geol. Soc., London, **9**, 1853, p. 12) described them as spore cases of Lycopodiaceae, upon which they were hailed as the oldest land plants. The same author, in his paper of 1889, changed his opinion of the nature of the fossils, and stated that they were probably of algal origin, an opinion in which Barber (1891) concurred. In the meantime, there had been considerable discussion of these objects, Dawson having considered them to be seeds, and others going to the extreme of doubting their vegetable nature. Doctor Duncan, in a comment on Dawson's paper (Quart. Jour. Geol. Soc., London, **38**, 1882, p. 108) suggested that the organism is the float or conceptacle of a seaweed.

Professor Riddle believed that the Bohemian specimens were of algal nature, and compared them with the floats of Sargassum. He called attention to the loose threads in the matrix of the central cavity as an indication of the degeneration of tissue in this region, and sections show that the air space was larger in some individuals than in others.

In Bohemia and in the Wenlock of England and Wales, Pachytheca occurs in limestones which carry an abundant and strictly marine fauna. In the Ludlow "bone bed," which consists of osseous and coprolitic matter, fish, eurypterids and a few poorly preserved brachiopods and molluscs occur with the little spheres. The shale beneath the bone bed is, according to Murchison, full of stems of "fucoids."

At the locality at Cardiff, Pachytheca was found in company with great quantities of fragments of Nematophycus, a gigantic seaweed which Dawson supposed to be a conifer. No connection between the two has, however, been proved. Scott (Encyclopaedia Britannica, 11th ed., article on Palaeobotany) states that in one case the "spherical thallus was found seated in a cup-like receptacle. There can be little doubt of the algal nature of the fossil, but beyond this it is impossible at present to carry its determination."

Spheres of Medium Size

The spheres of medium size (diameter 2 mm., Barrande, 1852, p. 276, pl. 27, fig. 2) were too few in the collection to use any of them in making sections. A fragment of limestone from the Silurian at Butowitz contains a small aggregation of them in a nearly circular area about 8 mm. in diameter. In this group there are about twenty specimens, crowded together, and many of them rather poorly preserved. The individuals exfoliate in the same way as the large spheres and probably have the same nature. They occur at the same horizon and localities as the large ones.

Spheres of Small Size

Plate **1**, fig. 5

The spheres of small size (diameter less than 1 mm., Barrande, 1852, p. 276, pl. 27, fig. 1) occur in great numbers in certain of the Devonian beds, all the specimens in the Museum of Comparative Zoölogy being from Stage G at Chotecz, Bohemia. They appear to occur in irregular aggregates, in some cases so abundantly as to be in contact with one another, in others disseminated through the rock. At first glance these specimens, of course, suggest oölites, but in thin sections it is seen that they have a definite brown to black outer envelope. This is in most cases filled with clear calcite. In very many of the sections the envelope is deformed, invaginated, wrinkled, or broken, showing that the envelope was weak. In this respect they differ markedly from the larger spheres. The outer coat of some of the best preserved specimens appears to be made up of numerous small cells, with wrinkles or spines on the surface. A few individuals show within the wall groups of smaller bodies like the containing one, but not circular in outline, and not of uniform size among themselves. In no case is the outer capsule entirely filled. One specimen contains two internal bodies, about which the outer wall has shrunk, another four, filling about one-half the area, still another has three. All these are in thin section no. 352. Such specimens suggest the sporangia described by Dr. Clarke from the Lower Middle Devonian of western New York (Amer. Jour. Sci., 1885, **29**, p. 288, figs 10, 13), and it seems not at all improbable that these Devonian "eggs" are spores or sporangia.

Capsule-shaped "Eggs"

Barrande, Syst. Sil. de Boheme, **1**, Suppl., 1872, p. 429, pl. 11, figs. 6, 11; pl. 18, figs. 30–33; pl. 35, figs. 21–32. Fritsch, Problematica Silurica, 1908, pl. 10, figs. 12, 13.

These "eggs" are elongate, cylindrical, with hemispheric ends, and are from 1.5 to 2.5 mm. in length, and 0.75 to 1 mm. in diameter. They occur always in masses, which Barrande classified as ovoid, cylindrical, discoidal, and irregular. These masses, which are usually from 10 to 30 mm. long, contain great numbers of individual capsules, and have very much the appearance of aggregates of eggs, suggesting particularly the ova of gastropods. Barrande seemed to favor the idea that these were the eggs of gastropods rather than trilobites, but Walcott, after finding similar bodies within a Ceraurus, was inclined to the belief that they were really the ova of trilobites. More recently Fritsch has figured a group of these bodies as the coprolites of an annelid or echinoderm, but has given no reason for this determination.

These specimens are all from the Ordovician, and the Museum of Comparative Zoölogy contains a number from Stage D-d_5 (Upper Ordovician) at Leiskow and Nusle. The state of preservation is such that nothing can be ascertained of the internal structure, so they must for the present remain as "problematica." It is safe to say, however, that they are of an entirely different nature from the spherical specimens described above.

Billings (Quart. Jour. Geol. Soc., **26**, 1870, p. 485), while searching for limbs of trilobites, had sections cut from enrolled specimens of *Calymene meeki* from Cincinnati. One of them, described and figured, contained large numbers of small ovate bodies in the crystalline calcite with which the interior was filled. These bodies were said to be about one-eightieth of an inch in greater and one one-hundredth of an inch in lesser diameter. Billings believed that these were eggs, but they seem to have shown no structure, being merely lighter colored and more opaque than the matrix. They were probably of the same nature as the similar bodies found by Walcott in Calymene and Ceraurus.

Walcott (Bull. Mus. Comp. Zoölogy, **8**, 1881, p. 216, pl. 4, fig. 8) has written briefly on the eggs of trilobites. The specimens which he investigated were in thin sections of Ceraurus. The individual "eggs" were much smaller than those described by Barrande, each being cylindrical, with hemispheric ends, about 0.5 mm. in longitudinal and 0.25 mm. in transverse diameter. Over two hundred such were seen in one section of Ceraurus, partly beneath the head and partly under the thorax, within the ventral membrane.

These "eggs" are seen in many sections of both Calymene and Ceraurus, and appear to be fusiform or spherical as well as cylindrical. In some specimens they are in the dark part of the matrix, but are more frequently found in the clear calcite which fills the space between the test and the ventral membrane. They do not seem to be confined to any particular region of the body, but occur beneath cephalon, thorax, and pygidium. This, and the fact that they are found in the fillings of the appendages as well as in the body cavity, suggest that they are really small oölites in the incipient stage of formation, with neither radial nor concentric structure preserved. These bodies and the ones found by Billings are of about the size one would expect the eggs of trilobites to be, but even if they are eggs, their location and preservation is such that they furnish no information about the location of the genital organs or the structure of the egg.

Summary

After a review of the literature, it can only be said that none of the specimens so far described has been proved to be the egg of a trilobite. The larger bodies considered by Barrande to be ova are certainly not such, and the smaller ones, even if correctly identified, have furnished no information of any value.

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2. The Systematic Position of the Archaeocyathinae

Since the time of the description of the genus Archaeocyathus by Billings in 1861, opinions have differed as to the nature of the organisms which secreted the skeleton so named. From the original suggestion that they were intermediate between corals and sponges, opinion has ranged from the calcareous algae or Protozoa to sponges or perforate madreporarian corals. This last disposition of them seems at present to be the "official" one, as it is adopted in the Eastman-Zittel Text-book of Palaeontology, and in many American text-books of Geology.

The present status of American opinion in regard to these animals was reached before the publication by Mr. T. Griffith Taylor of his splendid monograph on the Archaeocyathinae (Memoirs Royal Soc. of South Australia, **2**, pt. 2, 1910) of Australia. He was able to show that the animals could be classed neither as sponges nor corals, but occupied an intermediate position, possibly representing a group ancestral to both the calcareous sponges and the Anthozoa.

It is partly to call renewed attention to Mr. Taylor's excellent work on the morphology and classification of this group, and partly to record certain observations which some well-preserved specimens allowed me to make, that this article is written.

Taylor has pointed out that the skeleton in this group is essentially a hollow, double-walled cone, the walls joined to each other by vertical radially arranged septa which may or may not be supplemented by tabulae, synapticulae, or dissepiments. There is a great deal of variation in form, so that specimens may be conical, tubular, cup-shaped, saucer-shaped, or in extreme cases may have no central cavity, but grow as nearly flat expansions. Many species have the proximal end in the shape of a blunt point, showing a very small base for attachment, whereas others develop considerable thickness of exothecal tissue forming a wide, solid base, within which is the conical cup.

Taylor has emphasized the fact that the walls are the essential features of the group. Both of them have the appearance of a lace-like network, the perforations in the outer wall being generally smaller than those of the inner one. The space between the walls Taylor has called the intervallum and such septa or tabulae as cross it are, like the walls, highly perforated. The intervallum is of nearly constant width in all of the parts of the cup more than a half centimeter above the proximal end, and does not increase with the expansion of the cone.

Mode of Growth of the Skeleton

It is not uncommon to find, in various genera, e.g. Archaeocyathus, Spirocyathus, Ethmophyllum, and Pycnoidocyathus, species in which more or less pronounced annulations are developed. I was fortunate enough to find in material obtained by the late Prof. J. D. Whitney many years ago at Silver Peak, Nevada, three specimens, one of Ethmophyllum and two of Spirocyathus, which show that these annulations represent resting places in the growth of the skeleton. The Ethmophyllum was, before cutting in order to determine the genus, 12 mm. high, and in the upper 2 mm. expands from a diameter of 8 mm. to one of 10.5 mm. In this genus the pores of the inner are much larger than those of the outer wall. The specimen shows clearly that the inner wall extends entirely to the margin of the cup, where it joins the outer one. The intervallum is, therefore, entirely enclosed between the two walls.

A young Spirocyathus, 17 mm. high, shows on one side a rather considerable scar of attachment, above which there are concentric lines suggestive of an epitheca for a height of 9 mm. No pores are visible in the outer walls in this area. On the side opposite to the pronounced scar, the pores begin 7.5 mm. above the base. The first distinct annulation is 8 mm. above the base and there are six in all. There is general expansion of the cup up to the last annulation, then a very sudden contraction, so that whereas the diameter at the next to the highest annulation is 7.5 mm., it is only 5.5 at the top. In this case the aperture is so contracted that only a very small oval opening remains. As in the Ethmophyllum the inner wall joins the outer one, so that the the internal structure is entirely concealed.

A larger specimen of what appears to be this same species of Spirocyathus is about 57 mm. high and approximately 11 mm. in diameter 46 mm. above the base. It shows twelve prominent annulations, the highest of which is slightly less than the maximum diameter below. As in the other specimens, the walls meet, concealing the septa and other intervallar structures.

Taylor has pointed out that in all but four of the eighty species known to him, the inner portion of the cup is empty practically to the top. Further, he found, by making thin sections, that the inner and outer walls appeared to arise simultaneously from a basal plate, and that six primary septa arose together. His observations were made on Archaeocyathus, but numerous sections of Ethmophyllum from Silver Peak, Nevada, confirm his results as to order of septation. One such section, showing six septa, is .90 mm. in diameter. Another section, close beside it, is 1.5 mm. in diameter and shows eight septa. A section 3.5 mm. across has fourteen septa. Another of the same size has eighteen, and is the smallest I have seen which showed the vesicular structure which is characteristic of the inner wall in this genus.

Taylor found no evidence of regularity in the appearance of new septa. They probably do arise in pairs, but as shown by sections of Archaeocyathus from Silver Peak, they may arise from either the inner or the outer wall. Once they have grown across the intervallum, there is no way of differentiating a new from an old septum.

From the evidence cited above from specimens from Nevada, it appears that the upward growth is by periodic additions, the place of growth being on the summit of the intervallum. In the Coscinocyathidae the perforate tabulae are deposited at the time of constriction, being merely expansions of the inner wall. In the Archaeocyathidae and other families where tabulae are absent, new growth must have proceeded by resorption of that portion of the inner wall which overlay the intervallum. Evidence of this is seen in the shelves which project into the inner cavity in some species of Archaeocyathus and Ethmophyllum.

Taylor has commented upon the parallelism which exists between species of Archaeocyathus and Coscinocyathus. He says: "It is interesting to note that almost all the forms occurring in Archaeocyathus are duplicated in Coscinocyathus. There are the same changes from 'cone' to 'saucer,' while in several species the pores of the inner wall are of the same size as those of the outer wall." He then cites six species in each genus which do not differ greatly except in the presence or absence of tabulae. Considering the fact that the tabulae can only be gotten rid of by absorption, is it not possible that some of these parallel species are really identical?

Relationship to the Corals and Sponges

Taylor has pointed out that the Archaeocyathinae can in no wise be compared with the compound corals, nor with the imperforate Rugosa of the Palaeozoic, as would be most natural, but with the perforate Madreporaria, a distinctly modern type. They lack the directive septa of the "Tetracoralla" but equally fail of possession of the cyclical septal development of the Hexacoralla. The most cogent argument of all against placing them as corals is the present observation that the inner wall covers the intervallum. Taylor has already directed attention to the fact that the septa did not pass the inner wall and that no columellar structure was developed except in Somphocyathus and Anthomorpha.

Failing to place the group among the corals one must return to comparison with the sponges. In that group two difficulties are encountered. First, entire absence of spicules; second, presence of radial septa. On the other hand, many similarities are observed. If the skeleton is to be clothed in flesh it is readily thought of as a secretion of the mesoglea of a sponge. Such an interpretation would explain the exothecal deposition in those species with large bases, and, equally well, the absence of epitheca on the more numerous forms which lack it. It would account for the unlikeness of the pores of the outer and inner walls, for the absence of calcareous deposits inside the cup, and the general perforate character of all the skeletal elements. The method of growth accords with that of a sponge and it remains only to account for the presence of septa and the absence of spicules.

Among modern sponges, absence of spicules is considered a specialized characteristic, forms with a skeleton of spongin being descended from those with a more mineralized framework. Is it not possible that the ancestor of the sponges had a continuous skeleton which became degenerated into the form of spicules? The porous walls, tabulae, and septa of the Archaeocyathinae lend themselves admirably to such a view of the history, and, as Taylor has shown, in Dokidocyathus and Dictyocyathus we have two genera of this group which in great part lose the septa. Furthermore, *Archaeoscyphia minganensis* (Billings) from the Chazy, has a form so like *Archaeocyathus profundus* that they were originally considered as one species, but the former has been shown to have a spicular skeleton.

As to the origin of the septa there seems as yet to be no very plausible suggestion. Within the group, however, there seem to be two tendencies, one to loss of septa, as mentioned above, the other toward a greater development of them, so that in Metaldetes they meet in the center in the lower part of the cup, and in Anthomorpha the skeleton is, superficially at least, very like that of such a coral as Craspedophyllum. In Spirocyathus and Protopharetra the inner wall shows a tendency to break down. Although the wall is never quite lost, a coral-like form is simulated by some members of the group. In thinking of the animal it is possible to conceive that, the inner space being protected and more or less permanent by reason of the walls, the feeding cells may have migrated inward to unite in forming an inner digestive cavity, the growing cells around the osculum may, since they were youngest and most vital, have taken on sensory and capturing functions, and somewhere in the dark ages between the Lower Cambrian and Lower Ordovician, a coral developed out of an archaeocyathinid.

In our present state of knowledge, however, it can only be said that the Archaeocyathinae are more nearly allied to the sponges than to the corals. If they cannot be ranked as a phylum intermediate between the two and possibly ancestral to both, then they should be classed with the Porifera.

The description of two new species of this group follows.

Family ARCHAEOCYATHIDAE Taylor

Genus Ethmophyllum Meek

Ethmophyllum ceratodictyoides sp. nov.

Plate **2**, figs. 1, 2

A rather large, tubular, strongly annulated Ethmophyllum is represented in the collection by a single specimen about 60 mm. long. The enlargements, of which the fragment shows seven, are narrow, prominent, annular bulges, which near the middle increase the diameter from 18 mm. to 24 mm. The lumen is about two-thirds of the whole diameter and like the outer surface shows expansions and contractions, which do not, however, correspond exactly with the position of the bulges in the outer wall.

The pores of the inner wall are much larger than those of the outer one, the vesiculose inner layer is thin, and the septa close together. At the lower end of the fragment, where it is 16 mm. in diameter, there are about 60 septa. The bulges do not seem to affect the course of the septa.

No other Ethmophyllum with pronounced annulations has been described. At least two species of Archaeocyathus, *A. concentricus* Bornemann and *A. profundus* Billings, show similar bulges, but neither has a tubular shape. Closer comparison, externally only, however, may be made with the three species of Pycnoidocyathus described by Taylor.

The chief reason for describing the specimen, however, is its peculiar parallelism with the late Devonian hexactinellid, Ceratodictya.

Horizon and locality.— From the Lower Cambrian at Silver Peak, Nevada. No. 9,298 in the Museum of Comparative Zoölogy. J. D. Whitney collection.

Family SPIROCYATHIDAE Taylor

Genus Spirocyathus Hinde

Spirocyathus constrictus sp. nov.

Plate 2, fig. 3

Form elongate, tubular, with numerous annular constrictions. Central cavity about one-third the total diameter. Outer wall covered with small, irregularly arranged pores. Inner wall rather thick, but not vesicular. Intervallum crossed by irregular wavy septa which are strengthened by numerous tabulae and dissepiments so that the whole has a cellular structure.

This species is readily distinguished externally from the various Ethmophylla with which it is associated by the absence of longitudinal markings and the irregular nature of the pores of the outer wall.

Horizon and locality.— From the Lower Cambrian at Silver Peak, Nevada. Holotype no. 9,299; paratypes no. 9,313, Museum of Comparative Zoölogy. J. D. Whitney collection.

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3. Further Notes on Beatricea-like Organisms

Since my previous publication on this subject (Geol. Survey Canada, Mus. Bull. no. 5, 1914) I have collected a considerable amount of material, and have extended the known geographical range of *Cryptophragmus antiquatus* as far south as Virginia. It is the purpose of the present paper to record a number of new localities for that species and to describe three allied forms.

Family BEATRICIDAE fam. nov.

In erecting his family Labechidae, Nicholson (Palaeontographical Society, volume for 1885, 1886, p. 80) so worded the definition that it could include Beatricea. He considered the association a somewhat forced and temporary one, however, and ended his discussion by saying: "It may, however, be a question, whether, in view of its numerous peculiarities, it would not be expedient to regard Beatricea as the type of a special family" (loc. cit., p. 90).

The chief characteristics of the Labechidae are the "large-sized calcareous vesicles, which are usually lenticular in shape, and which are arranged in superposed strata as regards either a basal plane or an axial tube. These vesicles are traversed at intervals by 'radial pillars' directed at right angles to the plane of their strata. . . . No definitely circumscribed zoöidal tubes appear to exist."

Since the other members of the family are prostrate, encrusting growths, it seems advantageous to withdraw the elongate, upright forms from the group, and place them together under the name of their best known representative.

Beatricea Billings

Schuchert (Amer. Jour. Sci., 1919, **47**, p. 293) has questioned the validity of the name Beatricea, on the ground that Plummer (1843) gave the name Aulacera to the same kind of fossil that Billings described in 1857. Plummer did not name his species, but gave a figure which Schuchert recognizes as the fossil commonly called *Beatricea undulata*. Both *Beatricea undulata* and *B. nodulosa* are really but nominally species, as no very detailed or extensive work has ever been published on them. Since they differ considerably from one another, it seems possible that each may prove to be the type of a genus. Pending further investigation, it seems possible to retain the term Beatricea for fossils of the type of *B. nodulosa*.

An interesting observation recorded by Schuchert in this paper is in regard to the basal ends of specimens found in Anticosti. "Almost all of them are prostrate in the strata, having been broken from their basal attachments, but the latter are often seen, and some are quite large expansions, still stuck to the places where they grew" (loc. cit., p. 294).

For the present, at least, I shall continue to use the name Beatricea or species with nodose surface, unbranched habit, and no radial tubes in the outer zone. Radial pillars have been recorded in *B. nodulosa* and may prove to be generically important.

Beatricea gracilis Foerste

Plate **3**, figs. 5-7

Beatricea gracilis Ulrich (partim; nomen nudum), Bull. Geol. Soc. Amer., 1911, **22**, p. 327. Foerste, Dennison Univ. Bull., 1920, **19**, p. 195, pl. 23, fig. 7.

The first use of the name *Beatricea gracilis* in print was in connection with the description of the section at Blue Spring, a few miles southwest of Mercersburg, Pa. It was then stated that specimens were abundant in the thin limestone representing the Lowville of that locality. I visited this section in 1917, and obtained a large number of specimens and also found individuals of what appears to be the same species at Dickey, a few miles north of Mercersburg. Since those from the latter place are somewhat the better preserved, I have introduced figures of them as illustration of the species.

The name *Beatricea gracilis* was first legally published by Foerste, who credits it to Ulrich. Foerste's specimens were found in the Auburn limestone in Lincoln County, Mo., but appear to have the same characteristics as those in Pennsylvania. His brief description is as follows: "Stems 6 to 7 mm. in diameter, and several centimeters long, characterized by the presence of granules connected by the characteristic more or less anastomosing lines as in typical Beatricea. Strongly convex septal lamellae occur at intervals and occupy almost the entire width of the stems."

The following description applies to specimens found in the vicinity of Mercersburg, Pa. All of the specimens are slender, irregularly curved and so far as has been seen, unbranched. The outer surface is covered with low, elongate nodules, which appear to be arranged in a spiral fashion. In the interior, the chambered tube occupies the greater part of the diameter, and is surrounded by a thin zone of cystose tissue. The diaphragms are strongly convex upward, the chambers appearing like a series of hemispheres set one above another. These chambers are very much more regular than those of *Cryptophragmus antiquatus*. The curvature of the specimens is irregular with gentle bends, and the taper is very slight.

Measurements.— The diameter varies from 6 to 9 mm. in different specimens from Dickey. In the larger series from Blue Spring there are specimens from 6 to 12 mm. in diameter. A specimen from this latter locality, 130 mm. long, is 6 mm. wide at the lower and 5 mm. wide at the upper end. A specimen from a locality 2.5 miles east of Cumberland Gap, Tennessee, is 10 mm. in diameter. The tabulate zone of a specimen from Dickey is 2.75 mm. in diameter, and the cystose zone .875 mm. thick. A specimen from Blue Spring with a total diameter of 9 mm. has the tabulate zone 6 mm. in diameter, and there are eight chambers in 17.5 mm. along the median line. Another specimen has sixteen chambers in 30 mm. A larger one, 12 mm. in diameter, has ten chambers in 28 mm. and the cystose zone is only 1.5 mm. thick.

This species is, in external appearance, very like the type of the genus but differs internally in having a much smaller development of the cystose tissue. It is also, of course, of much less diameter.

From *Cryptophragmus antiquatus* it differs in lacking the radial zone and in being much more slender. From the form from Bellefonte, described below, it differs in lacking the branching habit and in having nodulose, spirally arranged surface markings.

Horizon and locality.— This species has so far been found only in the upper part of the Stones River. I have myself collected it at Blue Spring, Africa, and Dickey, all near Mercersburg, Pa.; at a railroad cutting 2.5 miles east of Cumberland Gap, Tenn.; one-half mile east of the station at Liberty Hill, Tenn.; and one-half mile east of the station at Lone Mountain, Tenn. One of the specimens from the latter locality is unusually large for an individual of this species and may be an imperfectly preserved Cryptophragmus. It is a large fragment, 160 mm. long, is irregularly curved, and 18 mm. in diameter at the larger and 11 mm. at the smaller end. The axial tube occupies nearly the entire diameter and the partitions are regular and rather distant, there being 9 in 44 mm. at the smaller end. A single individual of typical appearance was found in the Tyrone at Clay's Ferry, south of Lexington, Ky.

Thamnobeatricea gen. nov.

Among the common fossils of the strata with Tetradium at Bellefonte, Pa. is a Beatricea-like organism which is remarkable from the fact that it branches freely, giving it a shrub-like form. In structure it has the characteristics of Beatricea, and the new name is given solely because of its branching habit. The type is *Thamnobeatricea parallela*, sp. nov.

Thamnobeatricea parallela sp. nov.

Plate 2, figs. 4–9

This species occurs as slender, straight, or gently curved cylindrical branches which arise from an elongate central trunk at short intervals, and themselves branch, to some extent at least. The branching is not by bifurcation, but by lateral budding, the main stem remaining straight. The new branches tend to become parallel to the trunk, although to what extent this is true is not known, as no complete specimen has been seen. The specimens ordinarily collected occur as unbranched fragments of greater or less length.

The surface is marked by longitudinal ridges which have numerous tubercle-like crests. The ridges are close together, somewhat wavy and irregular in their course, but with no suggestion of spiral arrangement. Ridges occasionally die out and new ones begin, so that there are numerous minor irregularities. On some of the larger trunks the surface markings are decidedly nodulose and irregular.

The internal structure is much like that of *Beatricea gracilis*. There is a large central cavity crossed by hemispheric partitions with the arches convex upward, and a thin outer wall of densely cystose tissue, with distinct radial pillars. The partitions are considerably farther apart than in *B. gracilis*, and somewhat more irregular.

The type is a fragment of the main stem of a large branched colony. The trunk gives off eight branches in a length of 166 mm., two of them branched near their places of origin. The surface is not well exposed on the type, but there appear to be many large, irregularly placed nodules on some of the branches.

Measurements.— The main trunk of the type, broken at both ends, is 166 mm. long, 11 to 13 mm. in diameter at the upper end and 13 to 16 mm. in diameter 30 mm. above the lower end. The upper branch on the right hand side (of the photograph, pl. 2, fig. 9) is 107 mm. long from the axil, nearly circular in section, 10 mm. in diameter at the base and 9 mm. at the top, where it is broken off. The branch which it gives off is 8 mm. in diameter. A fragment 19 mm. long and 9 mm. in diameter, shows only three tabulae; another, 47 mm. long has 14; and a third, 43 mm. long, has eleven. A large unbranched fragment, broken at both ends, is 200 mm. long and 18 mm. in diameter.

Horizon and locality.— This species has so far been collected only on the foot wall of the large quarry north of the road from Bellefonte to Miles Gap, Pa., and about one-half mile west of the former city. It occurs with great masses of Tetradium at about the middle of the Stones River group. It has been seen at various other places on the strike of the same beds, as at Tyrone, Pa. The type was collected by Dr. R. M. Field and the writer, and is no. 9,302 in the Museum of Comparative Zoölogy.

Cryptophragmus Raymond

Cryptophragmus antiquatus Raymond

Plate 3, fig. 8

Cryptophragmus antiquatus Raymond, Geol. Surv. Canada, Mus. Bull. no. 5, 1914, pp. 1–10, pls. 1–4.

Since this species was described, it has been collected at a number of places somewhat remote from the original locality in Ontario.

Dr. Richard M. Field collected a single very well preserved fragment in the lower part of the Stones River at Loysburg, Pa. The weathered section is somewhat oval, 19 by 21 mm.; the axial tube is only 2 mm. in diameter, and the zone showing radial structure is 6.5 mm. thick. The structure is unusually well preserved.

The largest of several specimens collected by the writer from the Lowville at Dickey, north of Mercersburg, Pa., is also oval, and the section 12.5 by 15 mm. in diameter. The axial tube is 5 mm. in diameter.

A weathered longitudinal section from the Lowville, one and one-half miles west of Pennington Gap, Lee County, Va., is 18 mm. across at the larger end, and shows sections across some of the outer sheaths.

Cladophragmus gen. nov.

The discovery that some of the Beatricidae were of branching habit has emboldened me to describe as a new genus in that family a curious fossil which I have known for many years but have never found outside the typical locality.

This fossil has the appearance of a Thamnobeatricea stripped of its cystose tissue and is, in effect, a branching, tubular organism with hemispheric partitions, the outer wall thin, covered with small tubercles. Type, *Cladophragmus bifurcatus* sp. nov.

Cladophragmus bifurcatus sp. nov.

Plate 3, figs. 1–4

This species occurs as short, curved tubular fragments, no specimen much over an inch in length having been found. The tubes are irregular both in diameter and curvature and in many cases show series of irregular constrictions. Some individuals expand, others contract, in an upward direction. The surface is covered with numerous small irregularly placed pustules. Seen in section (pl. 3, fig. 2) these appear as solid outgrowths of the exterior covering, but as seen through the transparent filling of another specimen, they seem to be hollow. The partitions are convex, distant from one another, and cross the tube at the constrictions which are seen on the outer surface. The outer wall is rather stout, but shows no cystose tissue. Branching is by bifurcation, the two divisions diverging equally from the direction of the axis of the main stem, and being approximately equal in size.

Measurements.— One fragment is 34 mm. long, 7 mm. in diameter at the lower and 4.5 mm. at the upper end. Another fragment, 32 mm. long, has eleven chambers, whereas one 14.5 mm. long has but four. The best preserved individual showing bifurcation is 5 mm. in diameter, just below the place of branching, and each division has about the same diameter.

This species differs from *Thamnobeatricea parallela* in lacking cystose tissue in the outer walls, in having smaller and more irregularly placed superficial nodules, and in the method of branching.

Horizon and locality.— This species is common in one or two layers of the Lower Trenton in a quarry near the Montreal road, three miles east of Ottawa, Ontario. It occurs in layers of dark gray fine-grained limestone, in which it is associated with *Tetradium racemosum* Raymond. The cotypes are nos. 9,306–9,308, Museum of Comparative Zoölogy.

Summary

The present study has brought out some new facts in connection with the Beatricidae. It has been shown that certain forms, otherwise exceedingly like Beatricea, had a branching habit, and it thus becomes possible to confirm absolutely the previous impression that the partitions in the axial tube were convex upward. A distinct series has also been shown to exist, from Cladophragmus, with only a chambered tube, through Beatricea, in which the tube is surrounded with cystose tissue, to Cryptophragmus, which not only has the axial tube strengthened by cystose tissue, but has that surrounded in turn by sheaths pierced by radial tubes.

All of these tend to confirm the suggestion made in my previous paper, that the structure with which we are dealing was an internal axial support on which grew hydrozoan-like zoöids which in some cases secreted a calcareous framework about them, whereas in others they were supported by a gelatinous mass which was not preserved.

The following may be presented as a brief synopsis of the present taxonomic status of the members of the group:

Family BEATRICIDAE Raymond

Sessile hydromedusae with simple or branched calcareous skeleton consisting of a camerate tube which may be surrounded by cystose or by cystose and radially arranged tissue.

Genus Beatricea Billings

Colonies unbranched, axial tube surrounded with cystose tissue, often highly developed, and in some species containing radial pillars. Surface nodulose. Type, *Beatricea nodulosa* Billings.

Genus Aulacera Plummer

Similar to Beatricea, but with a strongly ribbed surface, and apparently without radial pillars. Type, *Beatricea undulata* Billings.

Genus Thamnobeatricea Raymond

Similar to Beatricea, but with branching habit, small development of cystose tissue and so far as known, no radial pillars. Type, *Thamnobeatricea parallela* Raymond.

Genus Cladophragmus Raymond

Branching camerate tubes without cystose or radial tissue. Type, *Cladophragmus bifurcatus* Raymond.

Genus Cryptophragmus Raymond

Unbranched colonies with both cystose and radial tissue surrounding the camerate axial tube. Type, *Cryptophragmus antiquatus* Raymond.

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4. Trails from the Silurian at Waterville, Maine

It is somewhat curious that a region so nearly unfossiliferous as central Maine should have furnished almost half of the organisms which, for Ebenezer Emmons, constituted the life of his "Taconic System." Professor A. Hopkins, one of Emmons' colleagues at Williams, called his attention to a piece of slate from Waterville, Maine. The fragment bore a trail which Emmons recognized as very like one illustrated in Murchison's Silurian System, a book which had appeared only two or three years previously. Shortly thereafter, probably in

1842 or 1843, Emmons visited Waterville, where Professor Justin R. Loomis showed him a large collection of trails, from which he described eight species. These he called *Nereites jacksoni, N. loomisi, N. pugnus, N. lanceolata, N. gracilis, N. deweyi, Myrianites murchisoni,* and *M. sillimani.* The types of these species cannot now be located, but the collection at Colby College contains well preserved material representing nearly all of them. Trails are rather common in loose pieces of shale along the bank of the Kennebec River, on the campus of Colby College, and also in the railroad cutting at Benton, three miles northeast of Waterville.

The interest aroused by the recent determination of the Silurian age of the Waterville shale by Professor Perkins (1924) seems to warrant a review of these oldest known fossils from Maine. My thanks are due to Professor Edward H. Perkins of Colby College for permission to study and describe the specimens.

Phyllodocites Geinitz

Phyllodocites jacksoni (Emmons)

Plate **4**, fig. 1

Nereites jacksoni Emmons, The Taconic System, 1844, p. 69, pl. 3, fig. 1. Nat. Hist. New York, pt. 5, Agriculture, 1846, **1**, p. 69, pl. 15, fig. 1.

Nereograpsus jacksoni Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, American Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 2.

Not *Nereograpsus jacksoni* Geinitz, Neues Jahrb. für Min., Geol. u. Pal., 1864, p. 6. pl. 2, fig. 4.

Not *Phyllodocites jacksoni* Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 2, pl. 1, figs. 1, 2; pl. 2, fig. 1.

This is the largest and most conspicuous trail found at Waterville, but it appears not to be common. It is somewhat irregular, only approximately bilaterally symmetrical, showing a series of overlapping oval depressions, from two to four abreast.

Description of a Specimen

Slab no. 1,175 in the collection at Colby College has on its surface an excellent specimen, showing a termination very clearly. The trail is of the "feeding" type. It turns back upon itself very sharply, both in the original specimen figured by Emmons and the one now studied. In this respect it differs from the Bavarian specimens referred to this species by Geinitz.

The trail, where most distinct, is about 28 to 30 mm. wide, but since the outer part is but lightly impressed, the conspicuous portion is only from 15 to 18 mm. wide. The shallow central furrow is from 4 to 5 mm. in width. It is flanked on either side by pairs of low, slightly curved, spindle-shaped ridges whose long axes make an acute angle with the axis of the trail. Outside each pair of ridges is a shallow, faint, semicircular depression, which is not preserved in other than favorable locations.

At the termination there is, on the median line, a broadly elliptical, nearly circular depression, with its longer axis in line with the direction of the trail. Within this depression there is a narrow median one which appears to be a continuation of the median furrow but which does not entirely cross the elliptical scar. This depression truncates the proximal end of the ellipse. The effect produced may be likened to the inside of the shell of an inverted, very slightly convex Agnostus. The major diameter of this truncated elliptical depression is 10.5 mm. and the minor one 9.5 mm. This is the same size as some, and slightly larger than others, of the faint lateral depressions along the trail.

The elliptical impression modifies adjacent ones, and is, therefore, the terminus and not the beginning of the trail. Its similarity to the other impressions shows that it is not the result of a burrowing action of an animal descending into the mud, but is the actual impression of the lower surface of the anterior end of the animal which made the trail.

A study of the impressions adjacent to the terminal one shows that the slightly curved spindle-shaped ridges mentioned above are due to the modifications of previously made impressions by the pressure of some object of the same size and form as that which made the terminal one. They appear not to be the impressions of the lateral appendages of an elongate animal, but represent successive positions of an object such as that which made the final impression. Since the lateral depressions are all of approximately the same size, it appears that the object which made them was sufficiently rigid to maintain its shape and thus suggests a shell of some sort. The outline corresponds with that of a Patelliform gastropod, if one imagine such a snail as carrying its shell above the anterior part of the body, with a part of the body behind it. The animal which made this trail, however, appears to have crept along, moving the shelled anterior end alternately from one side to the other, leaving a deeper or shallower impression each time the test came in contact with the mud. In this way it gathered its food, thoroughly gleaning from one small area after another. So far as I can learn, no living gastropod has any such habits or power of locomotion (Parker, 1911).

Interpretation

These trails are usually supposed to be those of annelids, but that ascription is difficult to support. It originated with MacLeay and Geinitz, who supposed the markings, now called trails, to have been the actual impressions of the bodies of worms, the latter having figured a specimen of a modern Phyllodoce with his description of Phyllodocites. If this contention could be upheld, one might believe that the fossils in question were made by annelids, for the lateral markings do very much resemble the leaf-like parapodia of some Polychaeta. It should be noted, however, that the lateral markings are much larger in proportion to the width of the median furrow than are the parapodia in respect to the width of the body of any annelid. It is true that in Nereis and the Phyllodocidae the parapodia bear foliaceous outgrowths of the same form as the oval lateral markings of Phyllodocites, but these noto- and neuropodia are of small size as compared with the body of the animal. They are, in fact, used for swimming and not for crawling along the bottom. Incidentally, it should be noted that many of the Phyllodocidae are purely pelagic, although other species lurk, during the day, under stones and shells in the Laminarian zone. In general, however, they are free swimmers and not crawlers.

Nereis virens Sars is a worm with foliaceous appendages on the parapodia and is reported to live between tides where it makes burrows in the clay. Since it is commonly known as the "Creeper," this is evidently a crawling worm, and it would be interesting to know what sort of a trail it makes.

The trail known as *Phyllodocites jacksoni* can hardly be that of any polychaet, because no annelid has any terminal structure which could make the sort of impression shown by the end of the specimen under discussion. Furthermore, as has been said above, the lateral markings are too wide in comparison with the median furrow, and there are no impressions of chaetae. It also seems doubtful whether an elongate animal with numerous pairs of parapodia would leave clean-cut impressions of the appendages. Probably the impressions of the anterior parapodia would become much blurred when tracked over by the posterior ones, unless all the motion is so coördinated that perfect "step" is kept. If the latter condition obtained, then we should expect to find no blurring of the trail, yet the specimen described shows distinctly that one impression has been overlaid by another. The new impressions, however, always have the long axis at a different angle from the old, showing a turning movement not consistent with the direction of the trail. If the action of the parapodia of different parts of the body was not "in step," then one would expect to find a terminal portion of the trail equal to the length of the animal, clean cut, the other part blurred. The present specimen is a terminal part, and it is blurred.

Gastropods and annelids, being, to my mind at least, eliminated as agents in the making of these trails, one naturally turns to the Crustacea. Trilobites are not sufficiently flexible to make a trail in the peculiar way in which this one appears to have been formed, that is, by the impressing of a laterally moved anterior shield. Notostracan branchiopods of the Apus type, or discinocarid phyllocarids, on the other hand, seem to fulfil the requirements exactly. They possess an anterior carapace of the proper shape, have a narrow, elongate body, and the proper amount of flexibility. Branchiopods are mostly swimmers, but members of the Apodidae have been seen to "wriggle along the bottom on their ventral surface." Notostracans of the proper form, such as Protocaris and Burgessia, are known from the Lower and Middle Cambrian, but unfortunately we have no further representative of the group till later than the Silurian. It is, however, very probable that similar animals existed in Silurian times.

Discinocarid phyllocarids being known only as fossils, there is no direct evidence as to the habits of the animals, but the depressed disk-shaped shields of Peltocaris, Discinocaris, and Aptychopsis suggest that these animals had a form not unlike that of Apus and Lepidurus.

Discinocaris, which is found in the Llandovery of Scotland in strata with *Monograptus flemingi* (Salter), has a form that is particularly like the sort of shell which would make an impression such as the terminal one of *Phyllodocites jacksoni*. *Discinocaris browniana* Woodward, like the other members of the Discinocaridae, appears to be a single shell, without the usual median line which makes bivalves of most phyllocarids. Such carapaces undoubtedly indicate animals with forms, and possibly habits, like those of the Apodidae, and Discinocarids may have had something to do with the formation of some of the "Nereites" trails of the Silurian of Great Britain. Crustaceans of this type have not, unfortunately, yet been found in the Waterville slates.

The present evidence seems to indicate that the animal which made the trails known as *Phyllodocites jacksoni* was a branchiopod or phyllocarid crustacean with a small, oval carapace and a more or less elongate narrow body. This animal had browsing habits, crawling along the surface of the mud, into which it sank but slightly. Its progress was not continuous, but in a series of short advances, each equal to about the length of the shorter diameter of the carapace. At each feeding station the uplifted carapace was allowed to rest upon the substratum in from four to five positions, usually within an arc of 60° on either side of the axis of the trail, so that all the area on either side was searched for food.

Phyllodocites pugnus (Emmons)

Plate **4**, fig. 3

Nereites pugnus Emmons, The Taconic System, 1844, p. 69, pl. 31, fig. 2; pl. 3, fig. 4; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 15, fig. 2; pl. 16, fig. 4; Packard, Proc. Amer. Acad. Arts and Sci., 1900, **36**, p. 64.

Nereograpsus pugnus Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28; Emmons, Amer. Geology, 1855, **1**, pt. 2, p.111.

Phyllodocites pugnus (Emmons) does not differ very greatly from *P. jacksoni*, and was apparently formed by the same sort of animal. The trails are not so wide as those of the latter species, but show the same sort of oval impressions, irregularly arranged in some portions of the trail, regularly overlapping in others. So far as can be judged from the specimens in the collection at Colby College, these trails could have been formed by smaller individuals of the same species which produced the wider one of *P. jacksoni*.

Nereites deweyi Emmons

Nereites deweyi Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 3; Manual of Geology, 1860, p. 87, fig. 64. Barrande, Bull. Soc. Geol. France, ser. 2, 1861, **18**, p. 300, pl. 5, fig. 19. Miller, N. A. Geol. and Pal., 1889, p. 519, fig. 940.

Nereograpsus deweyi Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 3.

Myrianites murchisoni Emmons, The Taconic System, 1844, p. 69, pl. 5, fig. 1; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 1.

Myrianites sillimani Emmons, The Taconic System, 1844, p. 69, pl. 5, fig. 5. Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 5.

The trail most commonly found in the shales at Waterville is the one which Emmons named *Nereites deweyi*. It is characterized by its uniform width, regularity, and the close spacing of the meanders. The width is about 5 to 6 mm.; the median furrow is narrow, slightly less than one-third the total width, and on either side are regularly spaced, raised, leaf-like markings, about 5 or 6 in 10 mm. Some of the better preserved specimens show a slight depression in each leaf-like scar, similar to that shown in Murchison's figure of *Nereites cambrensis*. Some specimens also show, faintly, lines across the central furrow of the trail. These continue the curves of the lateral raised areas, thus giving the impression of being the imprint of a shell with a nearly semicircular outline. The very general faintness or entire absence of this line across the median furrow indicates that it was secondarily obliterated by the forward motion of the animal, hence the inwardly converging diagonal axes of the lateral lobes of the trail point forward.

The animal which made this trail was probably unlike the one which produced *Phyllodocites jacksoni*, although of about the same size. Its habits must have been different, since it went constantly forward when browsing, instead of moving the carapace from side to side. The method of production of the trail would appear to have been much the same as that which can be observed by watching the common gastropods along our shores. The animal apparently crawled along the surface, the shell in contact with the substratum, thus pushing a small amount of mud in front of it. At regular and frequent intervals the test was lifted, thus producing a low ridge, convex forward. The narrow body dragging through this ridge divided it into two oval mounds. The appendages of the animal must have been small and used under the body, otherwise the lateral markings would have been destroyed.

If this animal were a crustacean, it must have been one with a carapace broader than the body, yet one which had no appendages outspread beneath the anterior shield, a condition not supported by our knowledge of living animals of similar form. Dawson, and later Packard, published figures of the trail of Limulus, an animal with a form somewhat similar to our hypothetical crustacean. The observations show that when crawling, the markings made by the anterior appendages are obliterated by hinder ones, so that in the resultant trail, depressions made by only the last pair persist. Transverse markings are made by Limulus only when swimming. The form is totally unlike that seen in Nereites. Observations on the trails of other living animals having numerous appendages show that the markings left are usually confused and more or less indecipherable.

In this connection, one must note that actual experience is sometimes at variance with theoretical deductions. Nathorst (1881, pl. 1, fig. 1) has figured the trail of a crawling specimen of the amphipod *Corophium longicorne* Fabricius. This little crustacean is a narrow, elongate, somewhat depressed animal with several pairs of long sprawling appendages, yet it makes a narrow regular trail not very different from that which we know as *Nereites deweyi*. There is a narrow median furrow, bordered by obliquely placed, leaf-like elevations which are separated by linear depressions which meet at angles of 75° to 90°, with the apex directed forward. Evidently it is possible for a many-legged animal which does not drag the body to produce a trail in which only the posterior pair of locomotor appendages leave impressions. This trail is very similar to that produced by the gastropod Purpura, except that where best preserved all its components are more straight-sided and angular.

Although it is possible that *Nereites deweyi* was made by a crustacean it seems much more probable that the agent in making such trails was a gastropod. In this connection I have already called attention to the figure of the trail *Purpura lapillus* copied by Nicholson and Lydekker. This trail is so exceedingly similar to that known as Nereites that there can be little doubt as to the origin of the latter. *Nereites deweyi* and *N. cambrensis* Murchison are so much like the "feeding trails" of modern gastropods that any other interpretation of them seems forced.

Myrianites murchisoni and *M. sillimani* have the same habit as *Nereites deweyi*. Specimens seem to show that they merely represent different states of preservation of the same typė of trail. In the forms which Emmons described as Myrianites the lateral lobes are faint or absent, but specimens show that one finds both conditions in the same trail. One specimen in particular which shows several meanders has the markings of *Nereites deweyi* on half the slab, and of *Myrianites sillimani* on the other half, changing from one to the other repeatedly.

Nereites lanceolatus Emmons

Nereites lanceolata Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 6; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 6 (*N. canceolata* on the plate).

Nereograpsus lanceolata Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 4.

Nereites lanceolatus does not differ greatly from *N. deweyi*, except that the lateral markings are, as the name implies, somewhat more accuminate. The trail is also somewhat more irregular, as the animal in wandering about failed to cover the surface fully. It must have been made by an animal very like that which produced *N. deweyi*.

Nereites loomisi Emmons

Nereites loomisi Emmons, The Taconic System, 1844, p. 69, pl. 3, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 15, fig. 3. Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 6, pl. 4. Packard, Proc. Amer. Acad. Arts and Sci., 1900, **36**, p. 64.

Nereograpsus loomisi Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 5.

Crossopodia loomisi McCoy, Syst. Descr. Brit. Pal. Fossils, 1855, p. 130.

Nereites gracilis Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 3. Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 6.

Nereograpsus gracilis Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, **1**, pt. 2, 1855, p. 111 pl. 2, fig. 6.

Nereites loomisi is of the same type as *N. deweyi* and *N. lanceolatus.* It differs from them chiefly in the smaller size of the lateral lobes, 8 or 9 in 10 mm., indicating less progress of the animal at each forward movement. The habit of the trail is about the same as that of *Nereites lanceolatus.*

As Geinitz has suggested, *Nereites gracilis* is probably not to be differentiated from *N. loomisi.* It probably would be as well to include *N. lanceolatus* under the same name.

Summary

The interpretation of trails is difficult and the results often unsatisfactory. Nevertheless, some progress can be made by careful analysis of the better preserved specimens. These analyses, however, can hardly be expected to lead to anything more than the prediction of the type of animal which made the trail. Only fortunate discoveries will satisfy as to positive identifications.

In the present study I have advanced arguments which seem to me to indicate that the trails known as Phyllodocites were made by an Apus-like crustacean, and that those denominated Nereites were formed by a gastropod. Both types were originally described as impressions of chaetopod worms. Many still hold them to be the trails of such animals. Richter has recently upheld the case for the annelids. He was able to observe one of the Phyllodocidae (*Eteone longa* Fabricius) and other nereid-like worms in the act of making trails. The trails proved to be straight, irregular, or regularly and symmetrically curved. The latter class is most interesting, as Richter argues with considerable reason, that trails up to 25 cm. in length showing repeated symmetrical curves of the same radius, turning constantly right and left, would only be made by elongate animals which progressed by rhythmic motions. This type of trail he calls the "free meander." The length of the worms creeping in these trails was from 3 to 4 cm. They were seen occupying from three to four curves of the meanders. These observations are of great importance and should enable us to identify some at least of our trails.

It should be noted, however, that these trails of chaetopods showed no trace at all of any of the lateral markings of Nereites or Phyllodocites, and confirm the theoretical conclusion that the markings of the individual parapodia would be obliterated by the passage of the body over the soft sand or mud.

The meanders traversed by these chaetopods were all open curves of comparatively large radius which do not show the sharp bends characteristic of what Richter has called "geführte Maeander," or what I prefer to call "feeding trails." In my previous paper I pointed out that such sharp turns could be negotiated readily by short animals, but could hardly be expected from elongate creatures. Richter seems inclined to think that trails of this type could be produced by annelids in spite of their similarity to the "Schneckenfrass" which he himself figures. To my mind, all the available evidence indicates that feeding trails were made by gastropods.

The question as to the naming of such things as trails remains an unsolved problem. It is, of course, absurd to give to tracks and trails generic and specific names, even if, by implication, we transfer those names to the animals which made the traces. It is obvious that a mature individual will produce a trail which will differ in some respects from that produced by the young. Observation also shows that the same individual will make very different sorts of tracks on soft mud, firm mud, soft or firm sand, and the tracks will differ whether made beneath or out of water.

As a practical matter, however, we need some sort of a name for a trail, just as much as we need a name for any kind of animal or plant. Further, we need a binominal name, if by names we hope to express any grouping by similarity. In what has been written above, I have used the term Phyllodocites, not as expressing any characteristics of any kind of animal, but to designate trails made up of overlapping, somewhat irregularly placed oval depressions on either side of a median furrow.

Nereites, as I understand it, should apply to feeding trails with a central furrow and regularly spaced, lateral, leaf-shaped elevations.

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5. On the Nature of Phytopsis Tubulosum Hall

Hall (Pal. N. Y., 1847, **1**, pp. 37, 38, pl. 7) described *Phytopsis tubulosum* as probably a marine plant. Since he included the fossil now known as *Tetradium cellulosum* in the genus Phytopsis, his hesitancy in making a definite reference to either the corals or algae is readily understood.

Vanuxem (Geol. N. Y., 1842, **3**, p. 39, fig. 3) had already presented a figure of the same fossil under Conrad's manuscript name *Fucoides demissus*. This figure was drawn by Emmons, and represented a specimen in a quarry at Fort Plain, N. Y. He unhesitatingly called it a plant, and made the observation that the distinctness of the fossil was due to "the plant having been removed, and the cavities which it occupied enlarged and filled with green and black shale, which strongly contrasted with the light dove-color of the rock." Opposite Fort Plain and near Palatine church the specimens were so numerous that Vanuxem remarked: "This vicinity appears to have been the favorite residence of this extraordinary fossil, their number there being so much greater than elsewhere."

Emmons (Geol. N. Y., **2**, 1842, pp. 108, 109, fig. 37) also discussed *Fucoides demissus*, but since in his district the fossils so called were chiefly Tetradia, his conclusion that the organism in question was a coral and not a plant does not really apply to *Phytopsis tubulosum*. He does, however, speak of the locality at Fort Plain, and explains the sudden extinction of the Fucoides there. He says, "Thus, on the immediate plane where the Trenton limestone is deposited, this fossil disappears, and no trace is to be seen in the succeeding rock; while up to the commencement of the Trenton limestone, it appears to have been in full vigor. The fact that it does not occur in the drab colored layers, though in the midst of the birdseye, throws some light upon the cause of its sudden extinction; they are impure limestones, and the matter deposited with the particles of lime exerted an unfavorable influence upon it. So the Trenton limestone, being composed of aluminous and other earthy matter in part, formed a medium which became unsuitable to their peculiar mode of living."

Since Hall's publication the *Phytopsis tubulosum* has been well known and frequently referred to, often under its pseudonym "Birdseye," but nothing of any importance has been written about it. Since *Phytopsis cellulosum* has been removed to the corals under the name of Tetradium, there seems to have been an impression prevalent that *P. tubulosum* was also a badly preserved Tetradium. This was, in fact, Emmons' view in 1842, but I find no more recent authority for such an opinion.

Since all of Hall's figured specimens were from Fort Plain, N. Y., that is to be regarded as the type locality. Typical specimens from a locality across the Mohawk from Fort Plain, consist of more or less vertical inosculating tubes usually nearly circular in section, and varying from 3 to 7 mm. in diameter. The limestone in which they occur is buff to blue-gray and weathers almost white, whereas the Phytopsis is usually brown, or has a brown outer covering and a central core of the same material as the matrix. As seen from above, the "birdseyes" appear to be scattered irregularly, although there is a suggestion of the rhombic arrangement observed by Emmons. In some cases the birdseyes are so close together that their edges touch one another; in others they are as much as 16 mm. apart in the specimen photographed (pl. 4, fig. 4) and there is no regularity of spacing in any of the specimens studied. In one area 100 mm. square there are 30 "birdseyes."

The layer being described is about 115 mm. thick, and although many of the Phytopsis penetrate through it, there are not nearly so many "birdseyes" on the lower as on the upper surface, indicating that many of the tubes are not 115 mm. long. On examining the sides of the layer, it appears that although in a number of cases a tube starting downward from the surface unites with another below, in no case does any tube show a blind ending downward. In fact, the condition of the lower ends of the tubes remains a subject for further observation.

The filling of the tubes is, as remarked above, variable. In the majority of cases there is an outer coating of brown material, within which is a filling of material like the matrix or of crystalline calcite. Others of the tubes seem to be entirely filled, especially in the upper portion, with the brown substance. A few, hardly distinguishable from the surrounding rock, are entirely filled with the same material as the matrix. Several, all much smaller than the average, contain crystalline calcite only.

The method of branching is variable. In some cases a tube appears to bifurcate, in others two parallel vertical tubes are connected by a more or less horizontal cross-tie, and in still others, 3 or 4 vertical tubes may be connected by a diagonal tube crossing from one to another. There is some evidence, though it is not conclusive, that all the tubes on a slab such as the one photographed are connected, and that they form a bushlike mass, expanding and branching upward. A colony of Syringopora, for instance, presents a similar plan of branching.

A certain amount of light is thrown upon the nature of *Phytopsis tubulosum* by specimens collected by the writer from the Lowville on the hill north of Little Falls, N. Y. These have the form of those from the typical locality, and the same method of branching, but all are filled completely either with brown and black material, or with calcite. On examining the beds in place, it was found that as usual, the Phytopsis was in the uppermost stratum of the Lowville, upon which rests the Trenton. At the contact, the Trenton is seen to fill small hollows in the Lowville and fragments of bryozoa and brachiopods, entire ostracoda and other shells of Trenton age form a part of the filling of the Phytopsis. Thin sections (pl. **4**, fig. 2) cut across the tubes some distance down in the layer show the filling to consist of brown matter somewhat concentrically arranged, but not lining the whole tube, and fine grains of quartz sand, partly angular, partly very well rounded and obviously wind-blown material. There are also a few grains of feldspar and various much decomposed fragments.

The material which fills the tubes being thus foreign to the Lowville, and, indeed, identifiable as being of Trenton age, indicates that the Phytopses at Little Falls were open holes at the beginning of Trenton deposition in this region. Apparently they were holes in firm material, for they have sharp boundaries clear to the surface. Moreover, the parting planes between the layers were well developed before the filling, for in one specimen the fillings are seen to spread out along the plane of stratification wherever a tube crosses it.

As mentioned above, many of the specimens from opposite Fort Plain show a concentric banding when seen on naturally weathered surfaces (see Pal. N. Y., **1**, 1847, pl. 8, fig. Ie), and when thin sections are made, it is found that the banding is due to a coating of fine sand grains which lines the tube. In the best of the sections, the central part of the tube is full of clear calcite, and around it is a sheath of a yellowish material in which are embedded minute grains of quartz, some of them rounded, others angular. On etching with dilute hydrochloric acid it is found that this lining is resistant. When the matrix surrounding the tube is dissolved away, the surface is smooth, and shows distinct longitudinal markings suggesting a slickensided surface, whereas faint distant constrictions suggest annulations.

The fact that these tubes from Fort Plain have a definite lining shows rather conclusively what the ones from Little Falls suggest, namely, that *Phytopsis tubulosum* is a burrow and, in all probability, the burrow of a tubicolous worm. The holes were apparently excavated while the surface of the Lowville was an exposed, partially hardened mud flat, and lined by the worm with sand brought in from the surface, cemented with mucous or perhaps a carbonate secreted by its body. One of the thin sections shows the tube lined with a substance in which small oölitic grains are the chief foreign material, and still other tubes seem to have no lining at all. This is, of course, a matter of preservation.

The probability that *Phytopsis tubulosum* was a burrow is strengthened by the fact that the specimens are always found in the highest layers of the Lowville, and also cut across the layers, never lying upon the surfaces. If it were a plant, coral, or any similar organism, one would expect to find the majority of the specimens lying prone along the parting planes, rather than in the position in which they grew.

Viewed in the light of the present interpretation, this Phytopsis comes to occupy an unusual position as the work, not of an animal which lived in Lowville or even Leray time, but in the interval between the two, and the species can be said to be characteristic, not of the upper Lowville, but of the *disconformity between it and the superjacent formation.*

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6. A Mid-Cambrian Gorgonian

Among the rarer fossils found in the Stephen shale on Mount Stephen at Field, B. C. are fragments which resemble parts of a reticulate graptolite. In 1927, one of the students in the Harvard Summer School found a nearly complete specimen, which appears to show the characteristics of a gorgonian, rather than those of a hydrozoan.

Gorgonians, rare as fossils, have not hitherto been found in strata older than the Cretaceous. Hence there is some uncertainty about the ascription of the present specimens to that family. There is, however, no *a priori* reason for supposing that the group may not be very ancient.

For fossils of this sort, it is necessary to institute a new genus, which may be called Petaloptyon, from the spreading, fan-like form.

Petaloptyon danei sp. nov.

Plate **4**, fig. 7

A sessile colonial organism whose chitinous skeleton is a fan-shaped network, apparently in one plane. Distally the margin is lobate; the proximal end is a rather broad but not expanded base, with one or more short, delicate fibrous anchoring processes.

Three of the radial elements of the network extend to the base, the median one the most prominent. The remaining radial elements appear to be branches of these. The branching is not, however, regular, although some of the radii are fairly straight; others, particularly in the middle of the fan, are irregular.

The transverse bars connecting the radial elements are evenly spaced on some parts of the fan, whereas in other areas they are somewhat irregular in arrangement. Although approximately at right angles to the radii, most of them slope somewhat backwards or forwards. The fenestra thus formed are therefore not of uniform size or shape.

Where best preserved, the skeletal elements appear to show longitudinal ridges and a spicular structure. They are partly replaced by pyrite, but the dark color suggests that they were originally chitinous. One specimen shows, near the outer margin, what appears to be a layer of disintegrated skeletal material. This contains numerous small rods, and some very small radial elements. One or two of the latter appear to be five-pointed, and suggest spicules of Eiffelia, as described by Walcott (Smithsonian Misc. Coll., **67**, 1920, pl. 86), but are very much smaller.

These spicules do not, it is true, very greatly resemble those of modern gorgonians. The latter are usually much more irregular, but this is due to the fact that they are composed of small crystals of calcium carbonate held together by organic matter. It is possible that earlier, non-calcareous forms had a simple type of horny spicule.

Measurements.— The most nearly complete specimen is about 50 mm. high and about 40 mm. broad. The fenestra vary from .75 mm. to 1.25 mm. in height. Fragments indicate that other colonies were somewhat larger.

Horizon and locality.— A rare fossil in the Stephen shale of the Middle Cambrian on Mt. Stephen, Field, B. C. Holotype (9300) collected and presented to the Museum of Comparative Zoölogy by E. B. Dane, Jr. Paratype (9301) collected by the writer.

Observations

The systematic position of this organism cannot be definitely determined, but there appear to be only three possibilities: it may be a sponge, a graptolite, or an alcyonarian. The presence of spicular elements suggests that it may be a sponge, but the fact that it is definitely planar and not conical and that it was apparently originally chitinous rather than siliceous tends to rule out this disposition of the specimen.

In general appearance it is much more like a graptolite than a sponge, and it may prove to be one of the Dendroidea. There is no evidence of thecae on any part of the specimens at hand, but this may, of course, be due to imperfect preservation. The chief reasons for thinking it is not a graptolite are that the distal margin is regularly lobed and seems to have a distinctly thickened border, and the presence of scattered spicules. Graptolites have not been found in the Middle Cambrian, but they may have been in existence at that time.

The genus Dictyonema contains those dendroid graptolites which have straight branches and regularly arranged dissepiments. The specimens here described could not be referred to that genus, because the initial portion of the colony is neither the simple nema of the true Dictyonema nor the root-like base of the shrubby types. The other dendroids have much more irregular branches and dissepiments than does Petaloptyon.

The general aspect of the fossil is that of the chitinous portion of the skeleton of a modern gorgonian. There is no evidence that it was ever invested with a calcareous coating, as are the modern forms. It may represent a primitive condition in the family. The spicular material observed in the outer portion of the fan very probably represents broken down skeletal elements. It is this structure which argues most strongly for reference of Petaloptyon to the Gorgonacea.

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7. A Middle-Cambrian Isopod-like Crustacean

Among the specimens collected by Dr. Walcott (Smithsonian Misc. Colls., 1912, **57**, p. 197, pl. 24, fig. 5) from the strata of Middle Cambrian age on Burgess Pass, B. C., was a single one which he named *Mollisonia gracilis*. In the summer of 1925 one of the students in the Harvard Summer School, Mr. J. D. Houghton, was lucky enough to obtain a second specimen which is probably of the same species, and which is now in the Museum of Comparative Zoölogy. This individual has a very well preserved anterior shield, the thorax is in fair state of preservation, but the posterior shield is considerably damaged at the distal end (Pl. **4**, fig. 6).

Description

Test very thin, elongate, narrow, parallel-sided. Head shield oval, about as long as wide, with two pairs of spines on the anterior end. The posterior part of this shield bears a narrow median ridge, which, about the middle, bifurcates, a branch extending to each of the median pair of frontal spines. The test has been slightly distorted, so that the shield is not quite symmetrical, and the right-hand branch shows an outer, submarginal fork not observable on the other side. About midway in the head, and near the sides, are elongate, crescentic markings which appear to be eyes. Each is situated on the outer slope of a very narrow sharp-crested longitudinal ridge, which, immediately in front of the eye-like spot, bifurcates, one branch turning toward each of the outer of the anterior marginal spines, the other turning inward toward the inner pair. Back of the "eye," each longitudinal ridge again bifurcates, one branch extending toward the genal angle, the other tending somewhat inward, but becoming lost before reaching the posterior margin. By combining the two outer branches of this ridge and a narrow groove forming the outer boundary of the "eye," a typical opisthoparian course of facial suture is obtained. In the middle of the shield on either side of the median ridge at the point of bifurcation, is a minute, raised, smooth-rimmed, circular, open-topped tubercle.

The median portion of the specimen has seven similar segments with short, blunt pleura. Curiously, there is no taper posteriorly. What appears to be the large flattened alimentary canal underlies the greater part of the axial lobe, and extends to the middle of the posterior shield, where there is a large circular anal opening. The posterior part of the anal shield is broken off in such a way as to give the appearance of a pair of fan-like caudal appendages, but this very probably has no structural significance.

Identification of the Species

This specimen differs in many respects from the figure of *Mollisonia gracilis* presented in Walcott's paper. His figure shows two conspicuous outer spines, enclosing five smaller ones on the anterior margin, and the cephalon is notably longer than wide. However, the correspondence in form, size and general proportions makes it seem probable that the published figure is inaccurate, and that our specimen belongs to Walcott's species.

The Generic Reference

The type of the genus Mollisonia is *M. symmetrica* Walcott (loc. cit., p. 196, pl. 24, fig. 3) described from a single specimen obtained from the Middle Cambrian on Mount Stephen, Field, B. C. The type is about 2.5 times as long as the specimens of *M. gracilis*, proportionately broader and the anterior and posterior shields are wider than long. The number of segments in the body, 7, is the same in both species. The structure of the head is, however, very different, *M. symmetrica* lacking the anterior marginal spines and longitudinal ridges. These latter features are so remarkable that it seems best to remove *Mollisonia gracilis* to another genus, which I propose to call Houghtonites, after the discoverer of the specimen here described.

Is *Houghtonites gracilis* an isopod? Walcott assigned Mollisonia to the family Microdiscidae Koken (Eodiscidae Raymond). It may be that the genotype, *M. symmetrica*, is an hypoparian trilobite. *Houghtonites gracilis*, however, although trilobite-like in its general structure, differs from any trilobite with which I am familiar in thinness of shell, thin, scalloped and spinose anterior margin, surface with longitudinal bifurcating ridges, and paired subcentral crater-like openings. Some Agnostidae do, it is true, have anterior marginal spines, but they are different in structure from those of *Houghtonites gracilis*, being extensions of the thickened border. Some trilobites also have thin shells, and it may be that this particular specimen was, at the time of death, in the soft-shelled condition following moulting. The other features are entirely unknown among trilobites.

The most primitive suborder of the Isopoda, the Asellota (Calman, in Lankester, Treatise on Zoölogy, pt. 7, 1909, p. 219) contains representatives with the same form as Houghtonites. The abdominal segments are fused into a single shield, there are seven free segments in the body, and the head in many instances shows a pair of scalloped recesses, indicating the position of attachment of the antennae and antennules. It is true that in many Isopoda there is a median rostral projection, but in this suborder there are many species in which the rostrum has a deep notch, so that there are two pairs of anterior spines. Among such species are *Jaeropsis marionis* Beddard, *Nannoniscus oblongus* Sars, *Desmosoma lineare* Sars, *Engerda tenuimana* Sars, *Echinopleura aculeata* Sars, and five species of Eurycope also described by Sars (Crustacea of Norway, **2**, 1899, pls. 50–69).

I have not found any isopod showing the system of ridges exhibited by Houghtonites, but *Janira maculosa* Leach, as figured by Sars (loc. cit., pl. 40), does show raised lines before and behind the eyes in the position of the facial suture of a trilobite, so corresponding to a part of the pattern of *H. gracilis*.

The paired median open-topped tubercles have the position but not the structure of the ocelli of eurypterids. If they were really ocelli, they would invite comparison with the Copepoda, but it is more likely that they are openings of glandular structures. Something of the sort appears to be present in Serolis, but their chief meaning at present seems to be a negative one, that is, they are structures unknown in trilobites.

In view of the fact that typical isopods are not known from strata older than the Jurassic, it would hardly be expected that the group had fully differentiated as early as the Middle Cambrian. If the appendages of Houghtonites were found, I imagine they would not be very different from those of trilobites. Even though the form is that of an isopod, it probably differed in many respects from modern members of that order. Its position then, appears to be somewhere between the trilobites and the modern isopods, in a group which, when it becomes better known, might be called the Protisopoda. The apparent fusion of the free cheeks to the median portion of the head is a feature to be expected in such a group.

The holotype of the genus is specimen No. 1811 in the Museum of Comparative Zoölogy, here identified as *Houghtonites gracilis* (Walcott).

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8. A New Reteocrinus

The genus Reteocrinus now contains five species of primitive camerate crinoids which flourished in Trenton and Richmond times. The present species, coming as it does from the Lebanon formation, is older than any previously known, and, so far as I know, is only the second crinoid which has been found in rocks of its age. The type, a single calyx with arms and about two inches of column, is exposed on the weathered surface of a small slab of limestone. The anal side adheres to the matrix, whereas the plates and three arms of the anterior side are well preserved.

Order CAMERATA Wachsmuth and Springer

Family Reteocrinidae Wachsmuth and Springer

Genus Reteocrinus Billings

Reteocrinus elongatus sp. nov.

Plate 4, fig. 5

Crown small, elongate, with strongly ridged calyx and slender arms. Column large, circular in section, columnals alternating in size with two to four small ones between each pair of plates of greater diameter. In the half inch near the calyx the columnals have thin frill-like expansions which are turned downward.

The infrabasals stand well above the column, and have on their upper borders depressions which form the lower parts of the sunken area in the lower part of the calyx. The basals are large and prominent, excavated at the top and sides. Radials longer than wide, tapering upward, very convex. Costals, four on two of the radii, five on the anterior one, all thick conical plates, with a sharp girder about the middle. Interbrachial areas depressed, covered with small irregular plates, only a few of which are preserved. Distichials, four, like the costals in appearance. Above the distichials the arms are imperfectly preserved, but in two cases bifurcate once more, the palmars being apparently four or five in number. No pinnules are preserved.

Measurements.— The crown is 27 mm. long and 7 mm. in diameter at the top of the basals. It is somewhat flattened. One of the basals is 2 mm. high and the distance on the anterior arm from the bottom of the radial to the top of the upper costal is 8.5 mm.; 45 mm. of the column are preserved. It is 2.5 mm. in diameter at the distal and 4 mm. in diameter at the proximal end.

Observations

This species is most closely allied to *Reteocrinus stellaris* Billings, the type of the genus. It differs from that, as from all other species of the genus, in having more costals. *Reteocrinus elongatus* has four or five costals, according to the arm. *R. stellaris* Billings has three, *R. alveolatus* Miller and Gurley has three or four according to the arm, *R. nealli* (Hall), *R. fimbriatus* Billings, and *R. magnificus* (Miller) all have two. It is interesting to note that all of the latter are from the Richmond, and that if the species be arranged in order of their occurrence in the geological formations, they form a regular series in which the older have the more costals. *R. elongatus* from the Lowville has four to five, *R. alveolatus* from the Lower Trenton has three to four, *R. stellaris* from the Middle Trenton has three, and all three species found in the Richmond but two.

R. elongatus agrees with *R. stellaris* also in having circular columnals, and in having depressed areas bounded above by the radials, laterally by the basals, and below by the infrabasals. Such areas are present also in *R. alveolatus*, but apparently absent from *R. nealli*, *R. fimbriatus*, and *R. magnificus*. These interbasal depressions are so prominent a feature of the three species which possess them that in most groups they would be recognized as of generic value, in which case the three species without them would be grouped in Miller's genus *Gaurocrinus*, of which *G. nealli* is the type. In any case the definition of Reteocrinus must be modified, as there are two species in which there are more than three costals.

Horizon and locality.— The single specimen on which *R. elongatus* is based was found by the writer in the Lebanon limestone in a railroad cutting about 2.5 miles east of Cumberland Gap, Tenn., in strata of Upper Stones River age, associated with *Beatricea gracilis*, Tetradium, and other fossils.

9. An Unusually Large Isoteloid Hypostoma

While collecting in the Chazy limestone on Valcour Island, N. Y., the writer happened upon the largest hypostoma he has ever seen, and a brief notice of it may be of interest to seekers after huge trilobites.

The specimen (Pl. **5**, fig. 2) is 125 mm., about 5 inches, long, and about 110 mm. in width. It was found lying dorsal (inner) side up and has been considerably weathered, so that little more than the outline can be satisfactorily made out. The prongs are nearly as long as the body, and the distance between their tips is 80 mm.

Hypostomata from 25 to 40 mm. in length are not uncommon in the Chazy, and have usually been referred to *Isotelus harrisi* (Seventh Rept. Vermont Geol. Sur., 1910, pl. 34, figs. 6, 7). These specimens are characterized by the unusual constriction of the anterior end of the body, so that it does not seem probable that the large individual here described belongs to the same species, as the anterior end is broad. A few fragments of a very large Isotelus were seen at the same horizon, and it is probable that when good specimens are recovered they will be found to differ considerably from either *I. harrisi* or *I. platymarginatus*, the two large Isoteli now known in the Chazy. As a convenient name for the animal I would suggest *Isotelus giganteus*, the hypostoma being, of course, the type. It was found at the base of the Upper Chazy on Tiger Point, Valcour Island, N. Y., and is no. 1,689 in the Museum of Comparative Zoölogy.

One cannot but speculate upon the probable size of the individual to which this hypostoma pertained. Large specimens of Isotēlus with the hypostoma in place have been but infrequently described or figured, so that the proportion of length of hypostoma to total length is but little known.

Hall (Pal, N. Y., **1**, 1847, pl. 62, fig. 2) figured a specimen of *Isotelus gigas* Dekay, 172 mm. long, in which the hypostoma was 28 mm. long. If the specimen from the Chazy had the same relative proportions, it would have been 768 mm. or about 30 inches long.

An *Isotelus megistos* Locke, from Cincinnati, Ohio, 125 mm. long, has the hypostoma 24 mm. long. With these proportions, *Isotelus giganteus* would have been 650 mm. or about 26 inches long.

An incomplete specimen of *Isotelus arenicola* Raymond estimated to have been 14 inches long (Ottawa Naturalist, **24**, 1910, p. 131, pl. 2, fig. 5) had an hypostoma 3 inches long, this being, next to the one here described, the largest hypostoma I have found recorded in the literature. With the same proportions, *Isotelus giganteus* would have been 25 inches long.

Estimates made in this way are liable to give an erroneous idea of the real size of the animal, but it seems probable that the individual to which this hypostoma belonged was not less than 24 nor more than 27 inches in length. With the breadth characteristic of all Isoteli, this great crustacean must have been truly the old man of the Chazyan sea. Would that his other appendages had been preserved to us!

Other Isoteli of approximately this size have been predicated on more or less fragmentary material. The most famous is the *Isotelus maximus* of Dr. Locke, and those fortunate enough to have one of his plaster casts can get a good idea of the probable appearance of *I. giganteus*, for the present hypostoma is of practically the right size for such an individual.

There seems, however, little doubt that Dr. Locke overestimated the size of the animal to which his fragments belonged. His first estimate of 21 inches was based upon the supposition that the pygidium would be one-third the total length, but on the basis of a specimen of *Isotelus megistos*, he later revised this to 19.5 inches (Second Rept. Geol. Sur. Ohio, 1839, p. 247; Amer. Jour. Sci., **42**, 1842, p. 366). The large fragment used by Locke was, however, very probably a small piece of an *Isotelus brachycephalus* Foerste (Bull. Denison Univ., **19**, 1919, p. 65, pls. 14, 14a, 15). In that case, the total length would have been but 18 inches.

Dr. Clarke mentioned a glabella of *Isotelus gigas* Dekay (Pal. Minn., **2**, pt. 2, 1897, p. 706, inserted fig.) from the Galena of Mantorville, Minn., which indicated an individual 17 inches long. The outline drawing gives no indication of the amount of the specimen actually preserved.

The largest known complete Isotelid is the *I. brachycephalus* recently described by Foerste. It is 368 mm. (about 14.5 inches) long. Next comes the impression of *I. arenicola* from near Ottawa, about 14 inches long. An Isotelus, probably *I. maximus*, whose estimated length was 384 mm., is represented by a thorax in the Museum of Comparative Zoölogy, and there is an *Isotelus maximus* in the Museum at the University of Toronto which is 285 mm. long.

Clark (Forty-fourth Rept. N. Y. State Mus., 1892, p. 111), reviewing the list of large trilobites some years ago, gave the palm to *Terataspis grandis* Hall, with an estimated length of 24 inches. Since that time, however, precedence has passed to the Ordovician *Uralichas ribeiroi* Delgado of France and Portugal. Oehlert (Mem. Soc. Geol. de France, no. **16**, 1896, p. 6) has estimated the total length at 700 mm. (about 27.5 inches), after allowing for the effect of crushing. Much of the length of this trilobite is, however, due to the long pygidial spine.

It is interesting to speculate on the significance of gigantism in trilobites. The most ancient of the huge fellows flourished in Mid-Cambrian time, whereas the last of them displayed his spiniferous coat in the early part of the Middle Devonian.

Trilobites a foot in length may fairly be called gigantic, for the average is probably less than 3 or 4 inches. The best known giants are listed in the following table, with the authority and country:

Middle Cambrian

Name	*Length*
Paradoxides tessini Brongniart	
Angelin. ? Sweden	About 300 mm.
P. spinosus (Boeck)	
Barrande. Bohemia	About 300 mm.
P. davidis Salter	
Salter. Wales	About 380 mm.
P. regina Matthew	
Matthew. New Brunswick	About 390 mm.
P. imperialis Barrande	
Barrande. Bohemia	About 400 mm.
P. harlani Green	
Walcott, Grabau, Raymond. Massachusetts	340–415 mm.

Ordovician

Name	*Length*
Megalaspis heros (Dalman)	
Angelin. Sweden	About 350 mm.
Schmidt. Esthonia	About 440 mm.
M. acuticaudata Angelin	
Broegger. Norway	About 403 mm.
"*Asaphus barrandei* de Verneuil"	
Barrande, Oehlert. France	400 mm.
Basilicus tyrannus (Murchison)	
Salter. Wales	About 300 mm.
B. marginalis (Hall)	
Raymond. New York	About 310 mm.
B. powisi (Murchison)	
Delgado. Portugal	400 mm.
Isotelus arenicola Raymond	
Raymond. Ontario	About 350 mm.

Name	*Length*
I. giganteus Raymond	
Raymond. New York	About 600 to 675 mm.
I. gigas Dekay	
Clarke. Minnesota	About 440 mm.
I. maximus Locke	
Locke, Foerste, Raymond. Ohio	About 460 to 480 mm.
I. brachycephalus Foerste	
Foerste. Ohio	368 mm.
Uralichas ribeiroi Delgado	
Oehlert, Delgado. France, Portugal	About 700 mm.
Brongniartella ? rudis (Salter)	
Salter. Wales	About 310 mm.

Devonian

Name	*Length*
Terataspis grandis Hall	
Clarke. New York, Ontario	About 510 to 600 mm.
Digonus gigas (Roemer)	
Beushausen. Germany	About 310 mm.
D. scrabrosus (Koch)	
Beushausen. Germany	About 350 mm.
Burmeisterella (?) *armata* (Burmeister)	
Beushausen. Germany	About 380 to 450 mm.
Trimerus major (Whitfield)	
Hall and Clarke. New York	390 to 400 mm.
Burmeisteria colossus (Lake)	
Lake. South Africa	About 500 mm.
Homalonotus sp. ind.	
Oehlert. France	About 400 mm.
Coronura myrmecophorus (Green)	
Hall and Clarke. New York	About 398 mm.
Dalmanites perceensis Clarke	
Clarke. Quebec	About 640 mm.

Although the above list contains a surprising number (28) of species which have furnished individuals 300 mm. or more in length, it will at once be noted that only five families are represented. In the Middle Cambrian there are six species of one genus, in the Ordovician thirteen species, representing six genera, and in the Devonian nine species belonging to eight genera. The variety of genera affording large individuals appears to increase greatly with the progress of time, although only three families are affected in the Ordovician and the same number in the Devonian. It has already been pointed out by Oehlert, that the time of maximum production of large trilobites coincided with the time of the greatest development of the group, and conspicuously large individuals were generally evolved rather late in the history of the family to which they belonged. This latter is particularly well exemplified by the Homalonotidae which differentiated from the Calymenidae in the Middle Ordovician, where most of the individuals are relatively small. Homalonotids reached considerable size in the Silurian, and then in the Lower Devonian are represented by six species of large dimensions. The Middle and Upper Devonian homalonotids are of good size, but not gigantic. Since every rule has its exception, it appears that *Brongniartella (?) rudis* (Salter) from the Ordovician of Wales reached a great size rather prematurely.

Another fact about the large trilobites is that there is nothing abnormal about them. The giants appear only in genera in which nearly all the individuals are large. If one should find an Agnostus, an Olenus, or a Proetus a foot in length, one would suspect it of being a monster. But so many of the Isoteli, Paradoxidae, Homalonotidae, and Dalmanitinae are large, that the huge individuals do not appear abnormal. Uralichas and Terataspis are rather exceptional, for most of the Lichadidae are relatively small, the Silurian Arctinurus being, of course, an exception. This same family produced the only really bizarre giant, Terataspis.

Burmeisterella ? armata is, it is true, provided with a certain number of spines, though not so many as Burmeister gave it, but spinosity did not, in general, accompany large size. Neither did the individuals of greatest size appear as heralds of the destruction of the group, but were rather the accompaniment of the period of greatest vitality. For example, the Asaphidae had their origin back in the Middle Cambrian, but remained rather obscure until the Ordovician, when they spread over the world in such luxuriance and variety, that they became the most common trilobites. They furnished eleven of the thirteen giants of the time, two in the Lower, seven in the Middle, and two in the Upper Ordovician. With the end of the Ordovician they disappeared, but the last of them were not so large as those of Middle Ordovician time.

10. A New Trilobite from Gaspé

Dr. C. W. Townsend of Boston has been good enough to present to the Museum of Comparative Zoölogy a very finely preserved mold of the dorsal surface of the pygidium of a Dalmanites which Mrs. Townsend collected at Gaspé. It represents an undescribed species, with an interesting ornamentation.

Dalmanites townsendae sp. nov.

Plate 5, fig. 1

Pygidium small, subtriangular, with a long median spine. The axial lobe is narrow, continuous with the terminal spine, and has seventeen rings, the posterior ones rather faint. The lateral lobes have fourteen pairs of ribs in addition to the anterior half rib. Each of the first ten pairs has a deep, narrow median furrow; the eleventh and twelfth pairs have shallow and faint ones; and the last two pairs are furrowless.

The surface is ornamented with tubercles which fall into three categories as regards size; firstly, large tubercles somewhat irregularly placed; secondly, tubercles of intermediate size symmetrically arranged; and lastly, small tubercles or granules in rows and rings.

The ornamentation of the axial lobe is regular and symmetrical. Each ring except the second, sixth, tenth and fourteenth, has an odd number (seven at the front, five near the posterior end) of tubercles of the intermediate size, the median one circular, the lateral ones elongate-oval in outline. The rings mentioned above as exceptions have no tubercles on the median line, but show a pair of large tubercles, one on either side of the axis, and a pair of the intermediate size beyond them. This regular arrangement of tubercles, in which every fourth ring has two large ones, makes a very striking and easily recognized pattern. Besides the larger tubercles, each ring has numerous small granules, some arranged in rings about the median pustules, others scattered irregularly over the surface.

The arrangement of tubercles on the pleural lobes is more easily illustrated than described. They seem at first glance to be irregularly scattered, yet when examined in detail, the two lobes are found to have their conspicuous tubercles symmetrically placed. Each of the first seven ribs on both lobes has five pustules which are located on the anterior side of the median furrow, but, when large, they interrupt it. On each segment one of the tubercles is much larger than the others, and these conspicuous ones are placed symmetrically on opposite sides of the axial lobe. If the tubercles be numbered from 1 to 5 outward from the dorsal furrows, the large pustule is number 1 on the first segment, 3 on the second, 5 on the third, 3 on the fourth, 5 on the fifth, 4 on the sixth, 5 on the seventh, 3 on the eighth. Behind the eighth pair of ribs the arrangement is not very definite, but the prominent tubercles appear to lie directly behind one another in a row parallel to the lateral margin. Besides these more conspicuous tubercles, the surface is ornamented with small granules which are arranged in more or less regular lines parallel to the furrows on and between the ribs, the line on the posterior margin of each rib being more conspicuous than the others.

The terminal spine has a deep dorsal furrow and the surface is covered with small granular tubercles.

Measurements.— The total length of the pygidium, including the spine, is 40 mm., width at front, 36 mm., length of spine, 11.5 mm., width of axial lobe at front, 9.5 mm.

Comparison with other species

It is, of course, natural to compare this trilobite first with the other species of Dalmanites which Clarke has described from Gaspé. Three only from that locality are known to have had a terminal spine of appreciable length: *D. perceensis* Clarke, *D. whiteavesi* Clarke, and *D. phacoptyx* Hall and Clarke.

The first of these has only a short terminal spine, which is not a continuation of the axial lobe, and the second has no pustules on the surface, so that detailed comparison is unnecessary. The form called *Dalmanites phacoptyx* invites closer attention. Clarke (New York State Mus., Mem., **9**, pt. 1, 1908, p. 123, pl. 7, figs. 5–10) states that pygidia referable to this species are common in the Grande Grève limestone about Grande Grève and elsewhere. The description states that there are twelve to fourteen pairs of ribs on the pleural, and thirteen to sixteen segments on the axial lobe, which is about the same as shown by our specimens. It is further stated that the caudal spine is about 15 mm. long and slender, but as the total length of the pygidium is not given, this measurement does not facilitate comparison. Nothing is said about the continuation of the axial lobe into the terminal spine, and the figures are not in agreement. Figures 9 and 10 on Plate 7 show the axial lobe terminating some distance in front of the posterior end (neither shows any trace of a terminal spine) whereas the right-hand specimen on the plate inserted in the text opposite page 124, although incomplete, indicates that the axial lobe did continue into the terminal spine. Three pygidia figured on plate 7 show the surface ornamentation. Figure 5 represents a fragment which is unlike *D. townsendae*, for there are rows of coarse tubercles on the part of each rib back of the median furrow. Figures 8 and 9 appear to show the same type of ornamentation. Each ring of the axial lobe has six tubercles, the median pair larger than the others. All the rings have the same number, so that the characteristic feature of *D. townsendae*, an interruption on each fourth ring by an odd number of tubercles, is not present.

The specimen already referred to as shown by Clarke on the inserted plate opposite page 124 is badly preserved, but the surface ornamentation is very much like that of *D. townsendae*. The sixth, tenth, and fourteenth rings on the axial lobe appear to have median tubercles, and the arrangement of conspicuous lateral tubercles appears to be as in our species. Although not definitely proven, I think the pygidia on this plate are conspecific with the one found by Mrs. Townsend. It remains to inquire as to which of the three forms described by Clarke from Gaspé is entitled to be called *Dalmanites phacoptyx*.

The original specimens of this species were more or less incomplete pygidia and a hypostoma from the Decewville at North Cayuga, Ont. (Hall and Clarke, Pal. N. Y., **7**, 1888, p. 31, pl. 11A, figs. 23–27). Only one of the pygidia (pl. 11A, figs. 23, 24) showed the terminal spine. It may now be designated as the holotype. The axial lobe is continuous with the spine of this specimen, thus agreeing with *D. townsendae* and the specimen figured in the text by Clarke, but the ornamentation, if correctly represented, is of a different type. The axial lobe appears to have eleven rings, with the tubercles on them irregularly placed, not in definite rows. The third and tenth rings each show a pair of high spine-like tubercles. The others have a median tubercle of variable size. This does not agree with the symmetrical alternation of our species, neither is it like that of either of the types of pygidia figured by Clarke (1908) on plate 7. If the name *D. phacoptyx* be restricted to forms agreeing with this one specimen, no specimens from Gaspé can be identified as that species.

The pygidium from which figure 25, plate 11A of Hall and Clarke was drawn, does, however, have the same ornamentation as that shown in figure 8 (and possibly fig. 9) of Clarke's report on Gaspé. Both appear to have paired median tubercles all along the axial lobe, which is, unfortunately, a common ornamentation in various genera of dalmanitids, hence it probably cannot be used as a specific characteristic.

Clarke (1900, p. 19, pl. 2, fig. 10) has identified *Dalmanites phacoptyx* in the Oriskany at Becraft Mt., N. Y. The incomplete pygidium figured is of about the same size and very like *D. townsendae,* but unfortunately the detail of the ornamentation cannot be made out. There appear to be more rings and ribs than in true *D. phacoptyx,* and the axial lobe lacks the conspicuous tubercles.

With our present incomplete knowledge of the species represented by these various shields, full comparisons cannot be made, but *Dalmanites townsendae* is distinguished from all the others by the symmetrical arrangement of the tubercles on the pygidium, and particularly by the positions of the large paired pustules on certain of the rings of the axial lobe.

Horizon and locality.— The holotype (Museum of Comparative Zoölogy, 1812) is a mould of the dorsal surface on a piece of yellowish, fine-grained and dense rock which does not effervesce with acids, and is probably a somewhat altered chert. The matrix contains a few fragments of brachiopods, but no recognizable fossils. It was found loose on the roadside at Grande Grève, Gaspé Co., Quebec. The exact horizon is unknown. Chert is, however, according to Clarke, very abundant in his Division 2 of the Grande Grève limestone. Exposures of it are found in many places on the southern slope of the Forillon. *Dalmanites phacoptyx* was listed from this division, whose age appears to be Oriskany. The slab figured by Clarke (1908, opposite p. 124), the specimens on which are believed to be *D. townsendae,* was found loose on the hills behind the Peninsula, so that its exact horizon is also unknown.